Impacts of climate change on marine fisheries

East Coast Climate Change and Fisheries Governance Workshop

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Introduction

- Jon Hare, NOAA Fisheries
- Worked in Caribbean, Gulf of Mexico, Southeast U.S. and Northeast U.S.
- Currently oversee oceanography programs in Northeast
- Director, NOAA Narragansett Laboratory

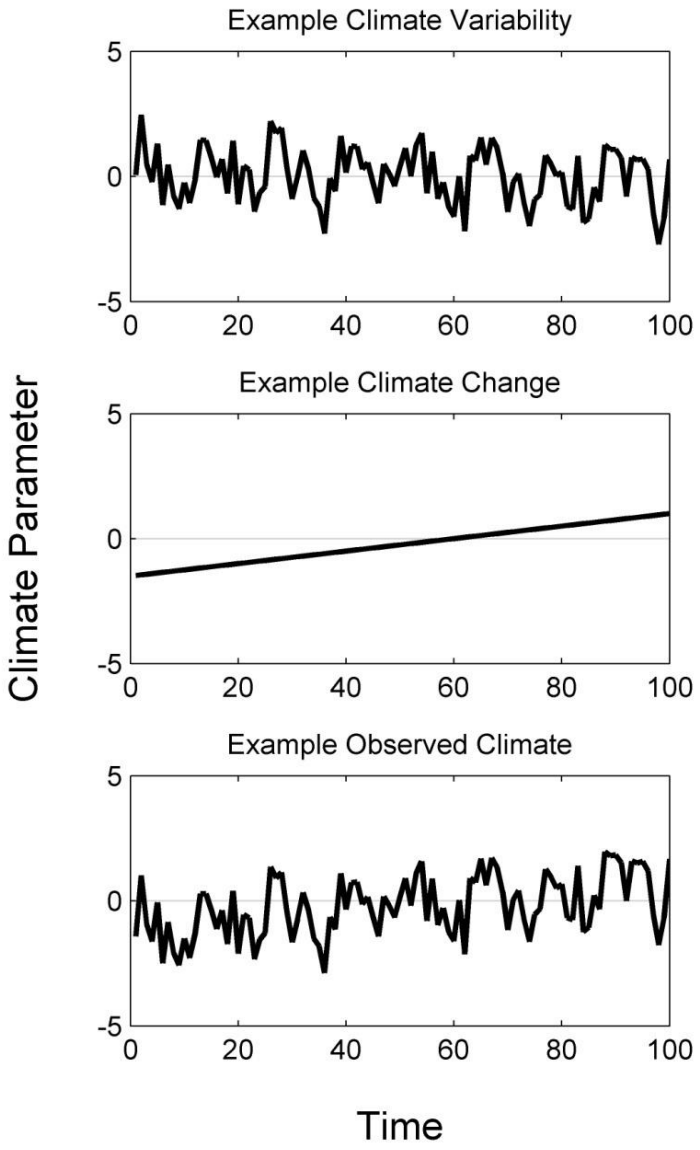
Outline

- Climate Variability and Climate Change
- Past and Future Climate States
- Impacts on Fishery Resources
- Conclusions

Many examples are from Northeast

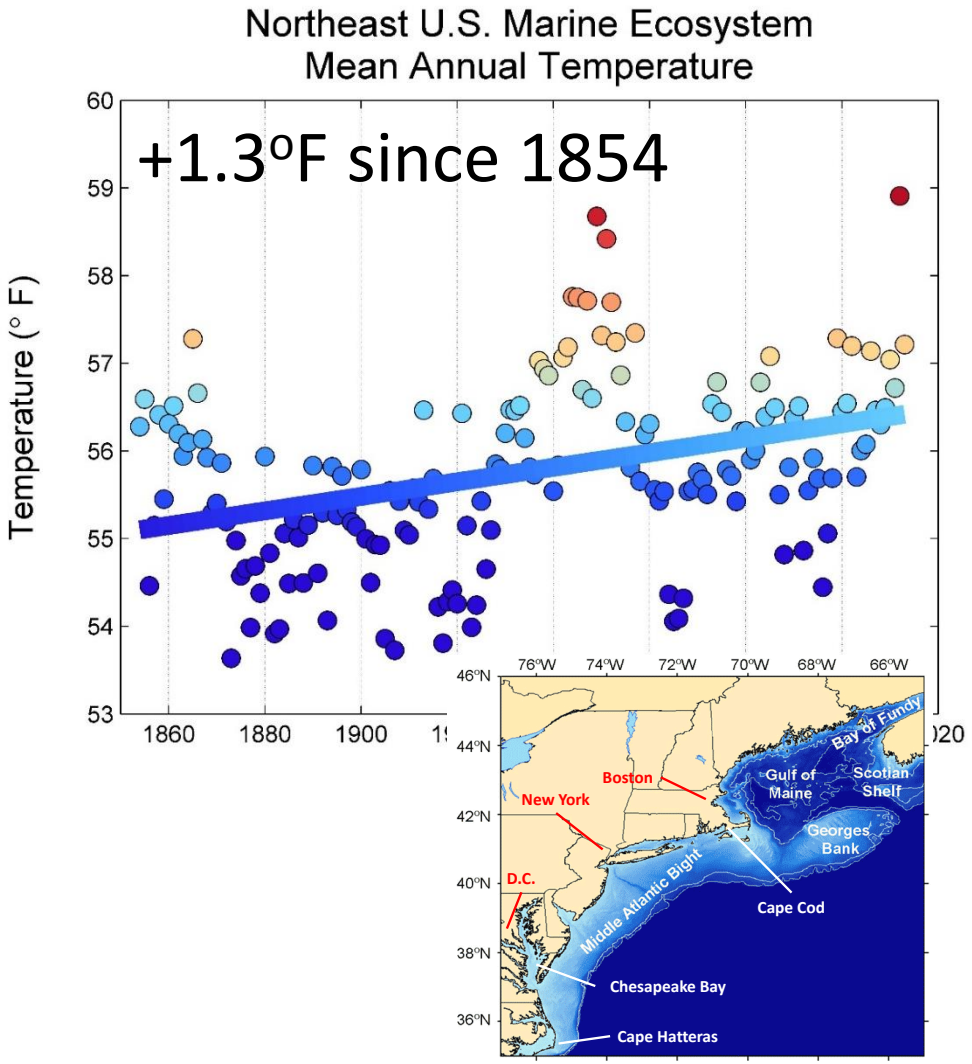
Climate Variability and Climate Change

- Important difference "climate change" vs "climate variability"
- Climate variability – natural variability within the climate system
- Climate change – long term change in the climate system



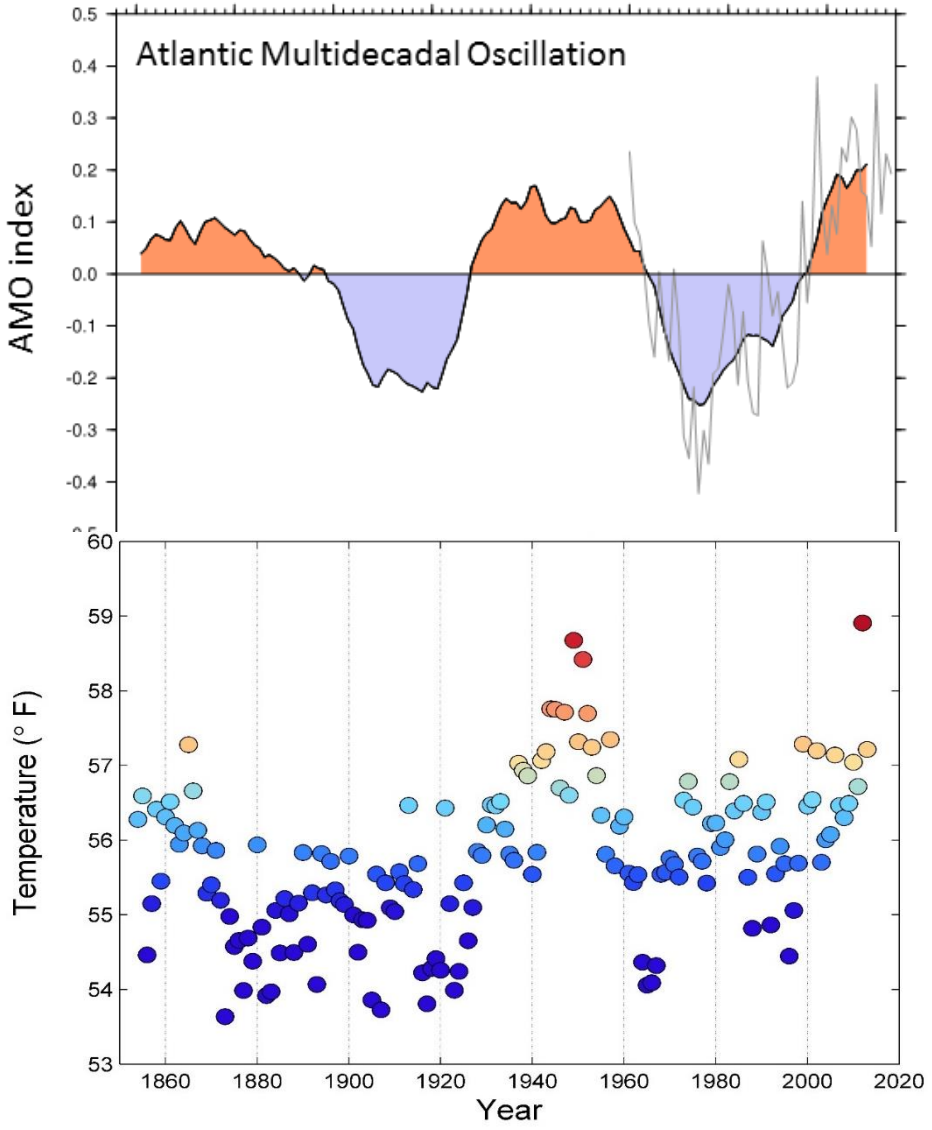
Climate Variability and Climate Change

- <u>Climate variability</u> – natural variability within the climate system
- <u>Climate change</u> – change in the climate system



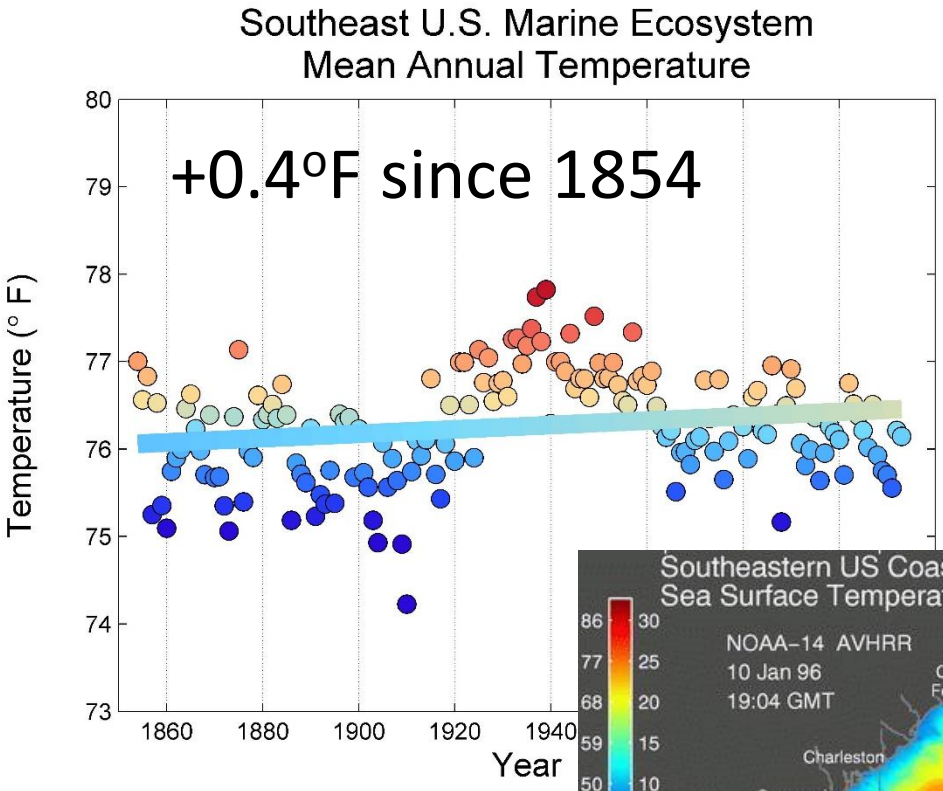
Climate Variability and Climate Change

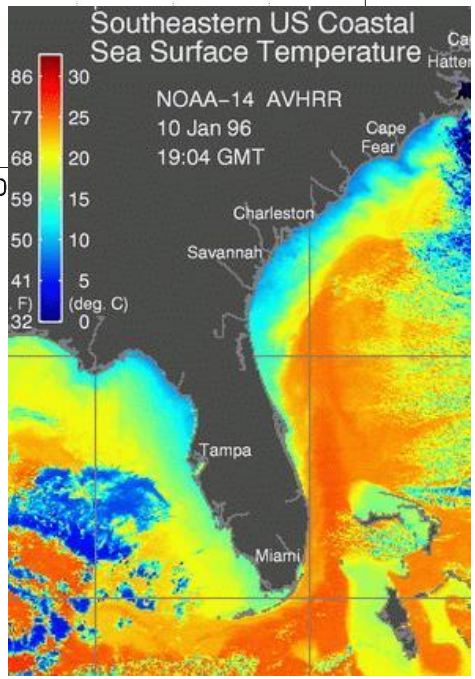
- Interannual variability
- Atlantic Multidecadal Oscillation
- North Atlantic Oscillation



Climate Variability and Climate Change

- <u>Climate (Regional) variability</u>; Southeast warming much less than in Northeast
- <u>Climate change</u> – change in the climate system

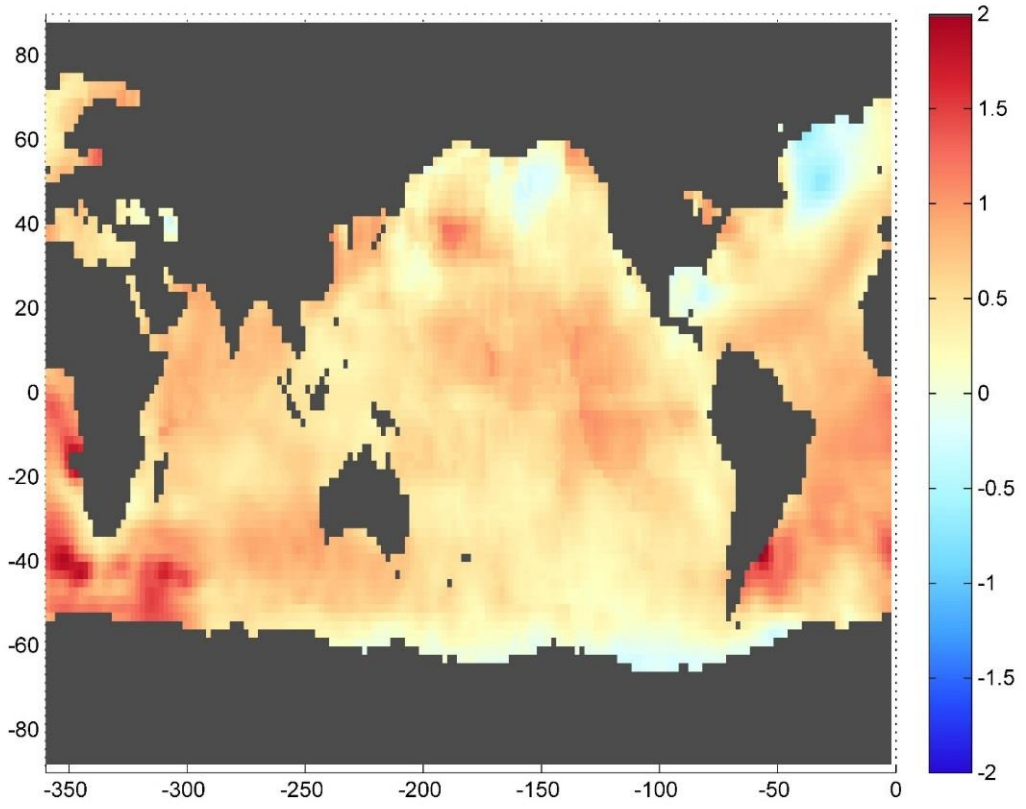




Climate Variability and Climate Change

- Scale of climate variability and change relatively large
- Consistent over 100s-1000s km
- Differences across Cape Hatteras boundary

Temperature Change 1854-present




Questions?

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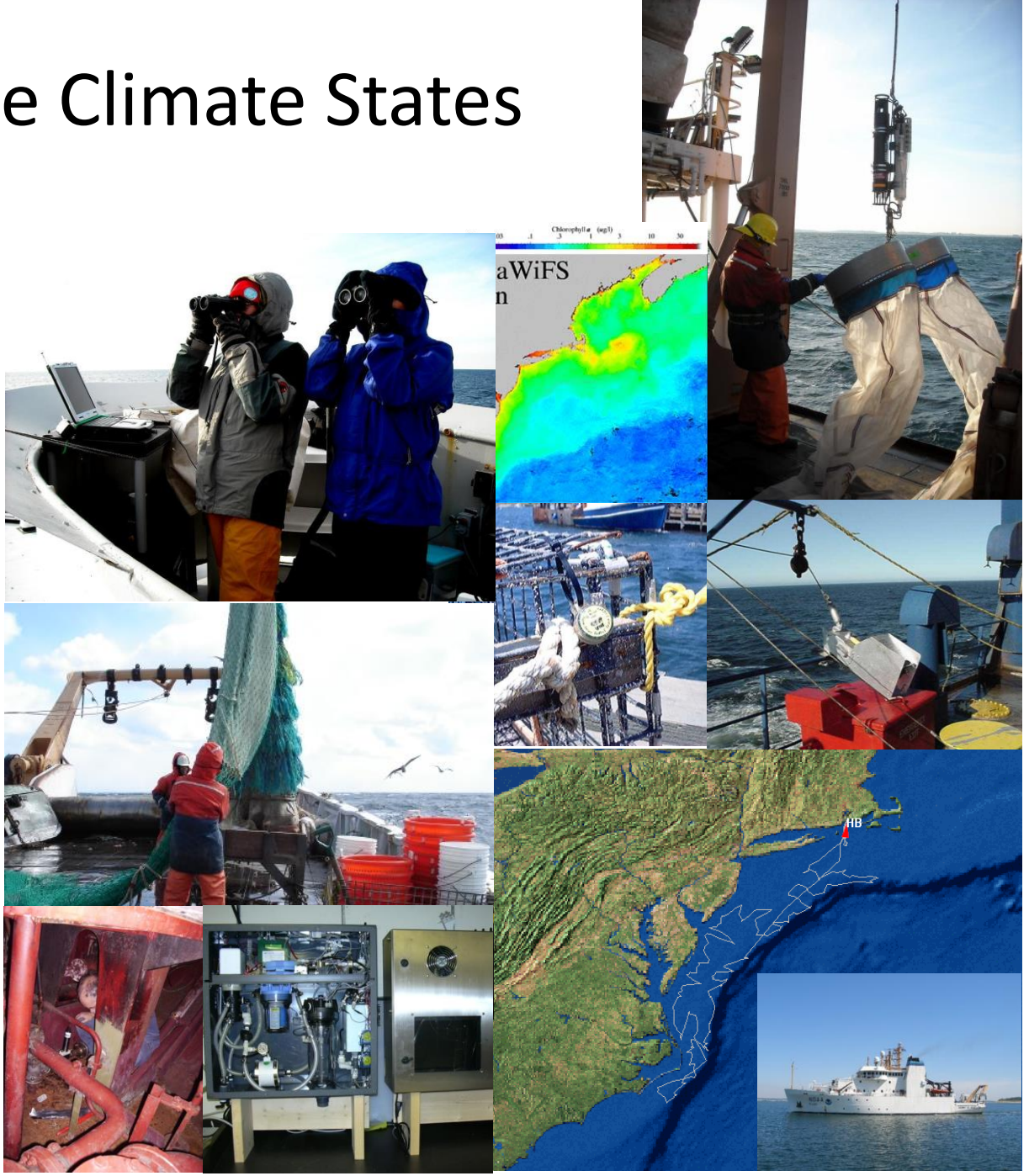
https://student.societyforscience.org/article/gorgeous-eco-bullies

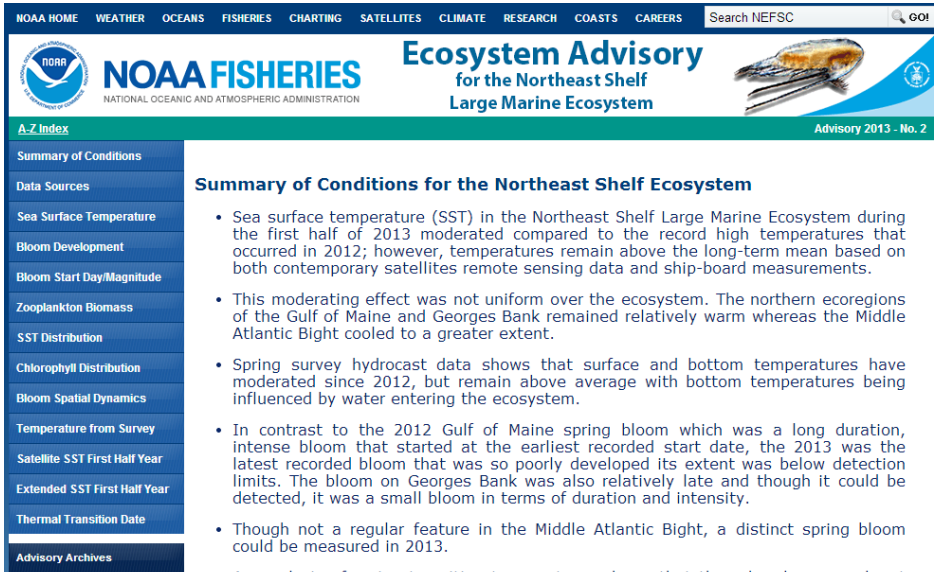
Past and Future Climate States

- Past and current states are based on observations (many NMFS obs are now at risk of ending)



Past and Future Climate States

- Much of the information is from NEFSC Ecosystem Status Report and Ecosystem Advisories
- Ecosystem Assessment Program (NEFSC)

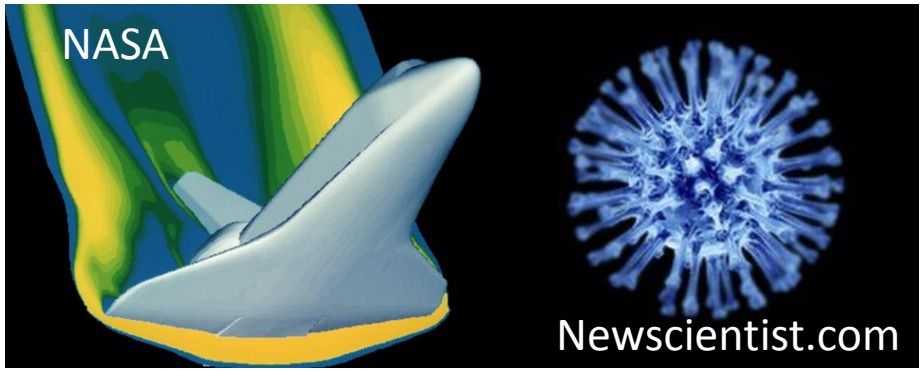


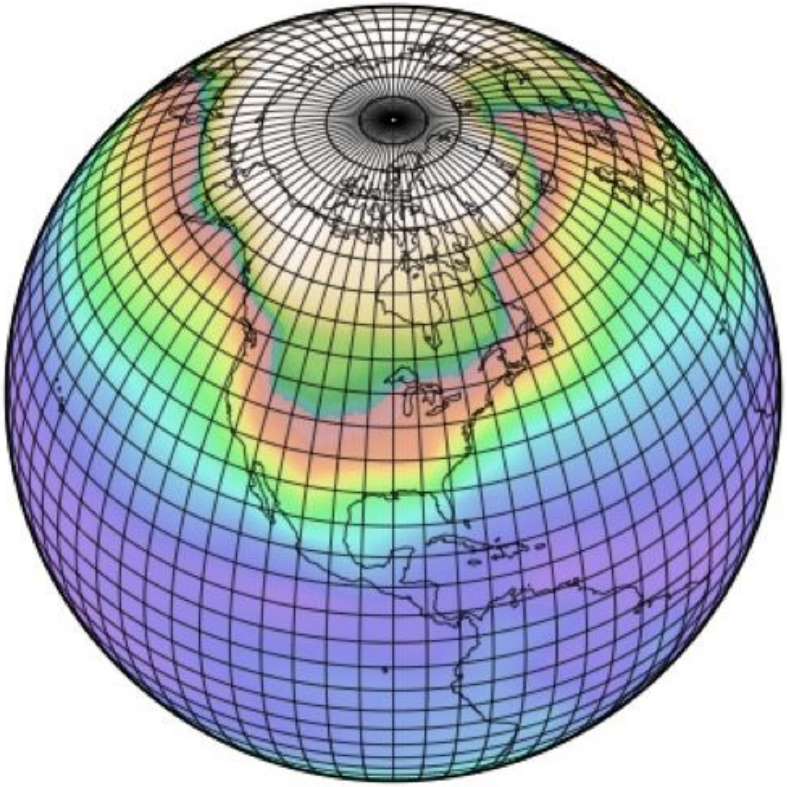
Northeast Fisheries Science Center Reference Document 12-07

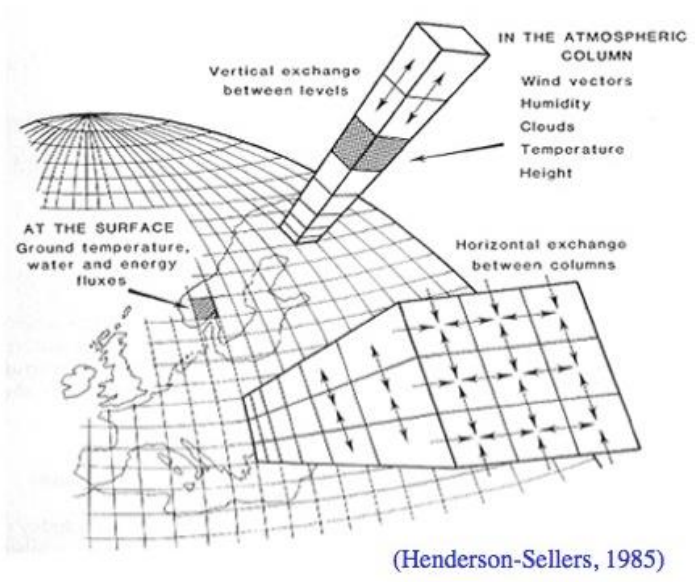
Ecosystem Status Report
for the Northeast Shelf Large Marine
Ecosystem - 2011

Past and Future Climate States

- Future states simulated with models



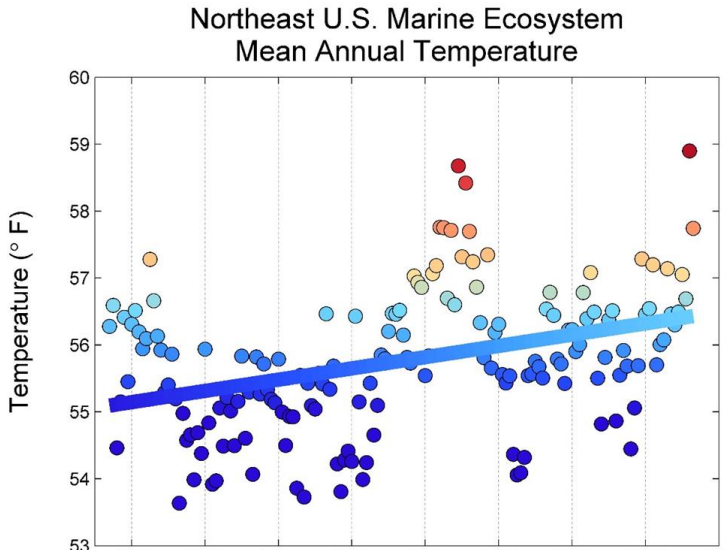


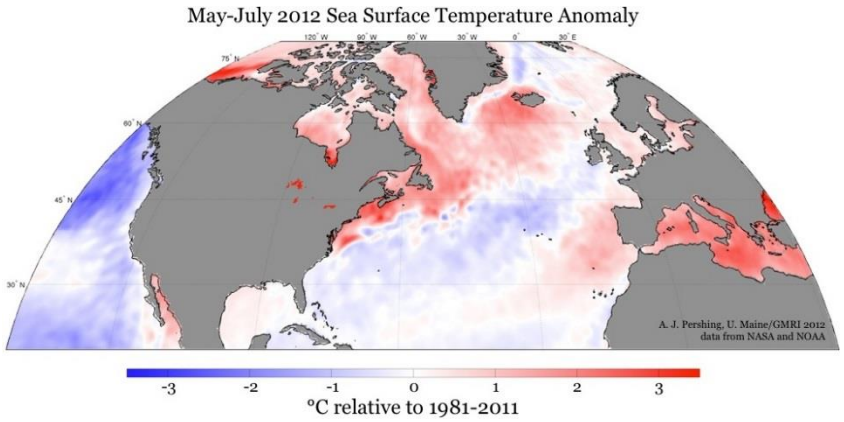


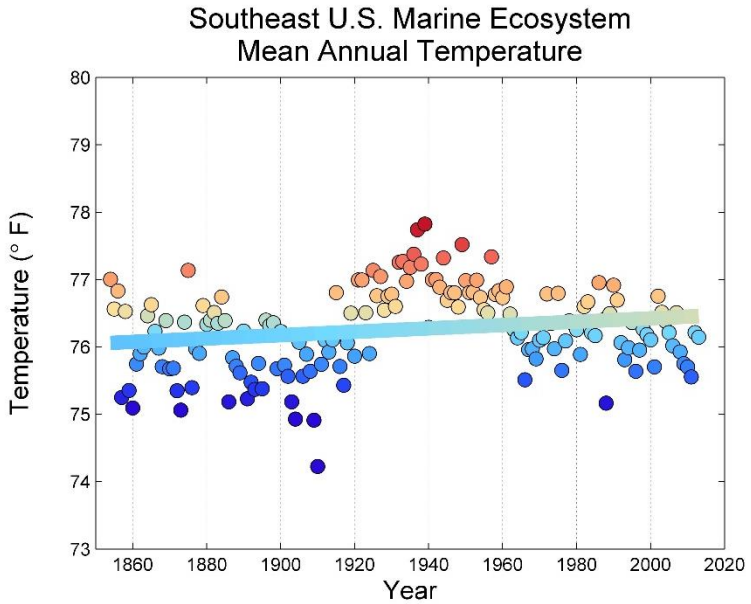
http://serc.carleton.edu/eet/envisioningclimatechange/part_2.html

Past and Future Climate States

- Since 1960
- Warming in NE
- Constant in SE
- 2012 warmest on record in NE



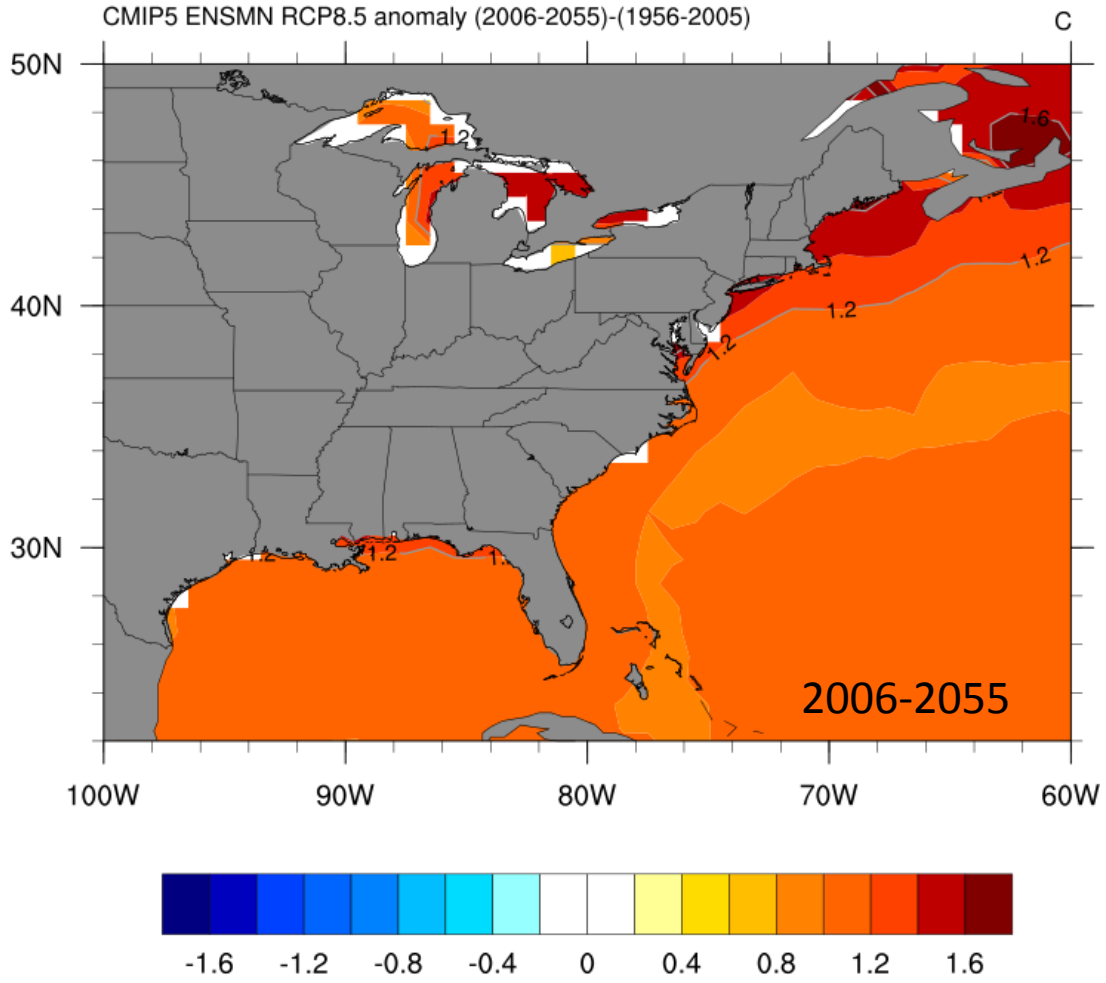




http://www.seascapemodeling.org/cgi-bin/mt/mt-search.cgi?blog_id=2&tag=climate&limit=20

Past and Future Climate States

Climate projections – Surface Temperature



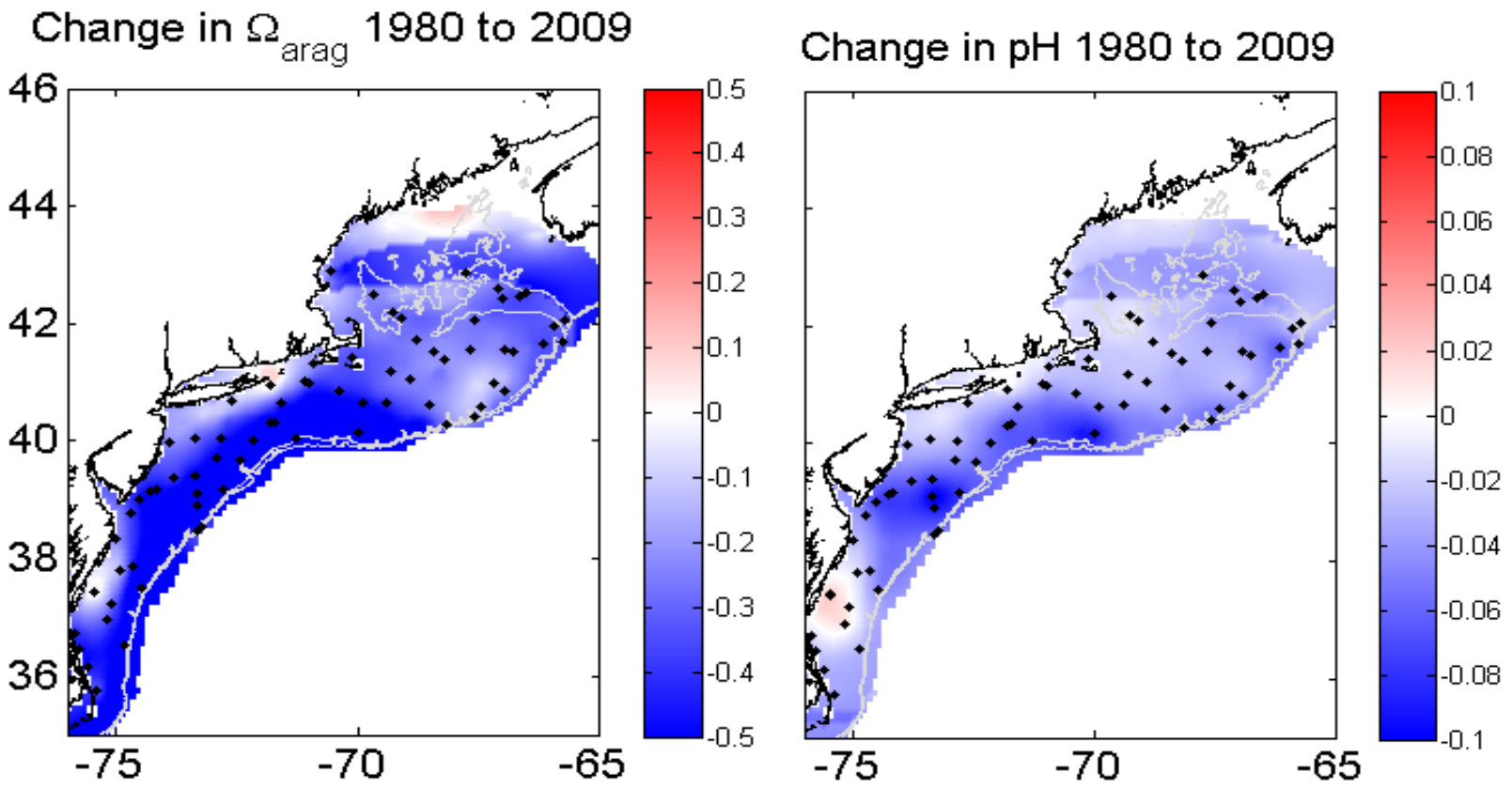
- Increase 1.3°F in past
- Increase ~1-2°F in coming decades

Jamie Scott & Mike Alexander – NOAA OAR ESRL

http://www.esrl.noaa.gov/psd/ipcc/ocn/

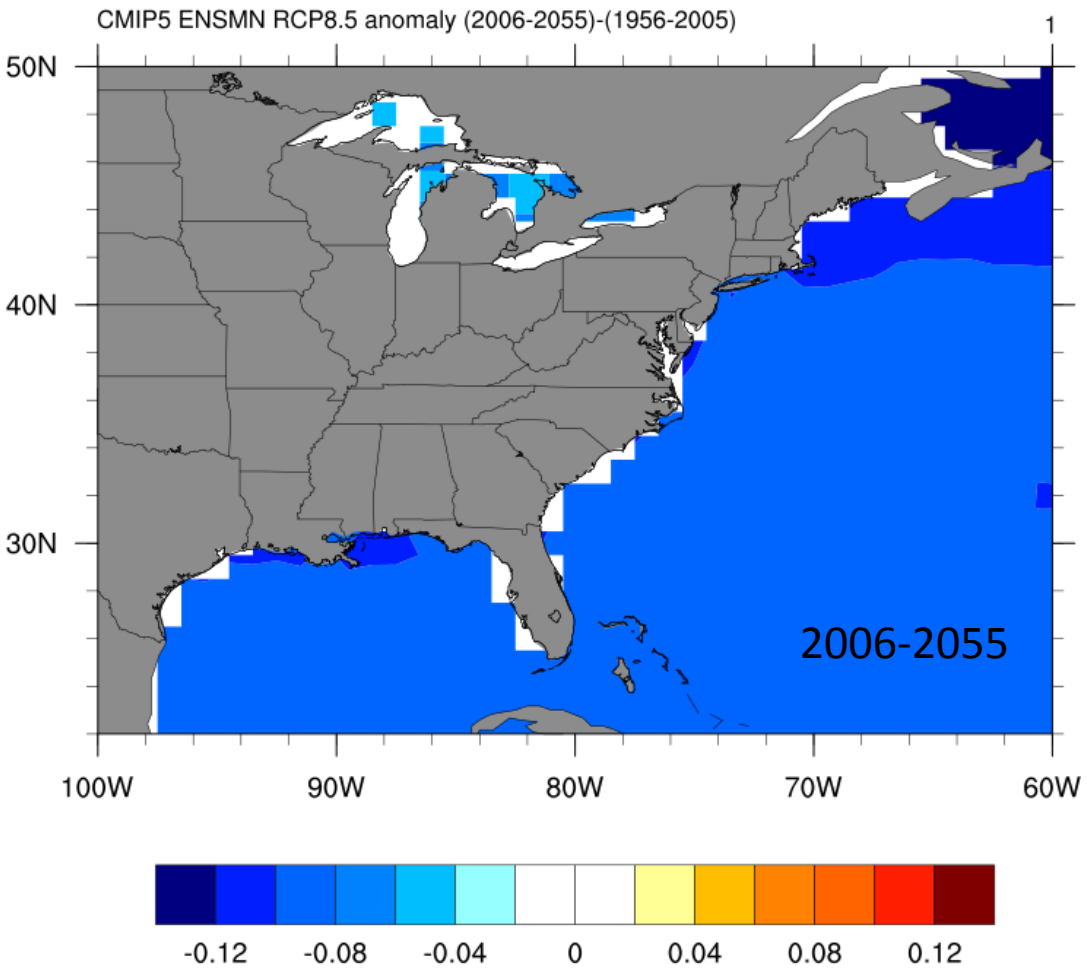
Past and Future Climate States

- Ocean acidification is occurring
- Regional and seasonal variability



Past and Future Climate States

Climate projections – Ocean Acidification



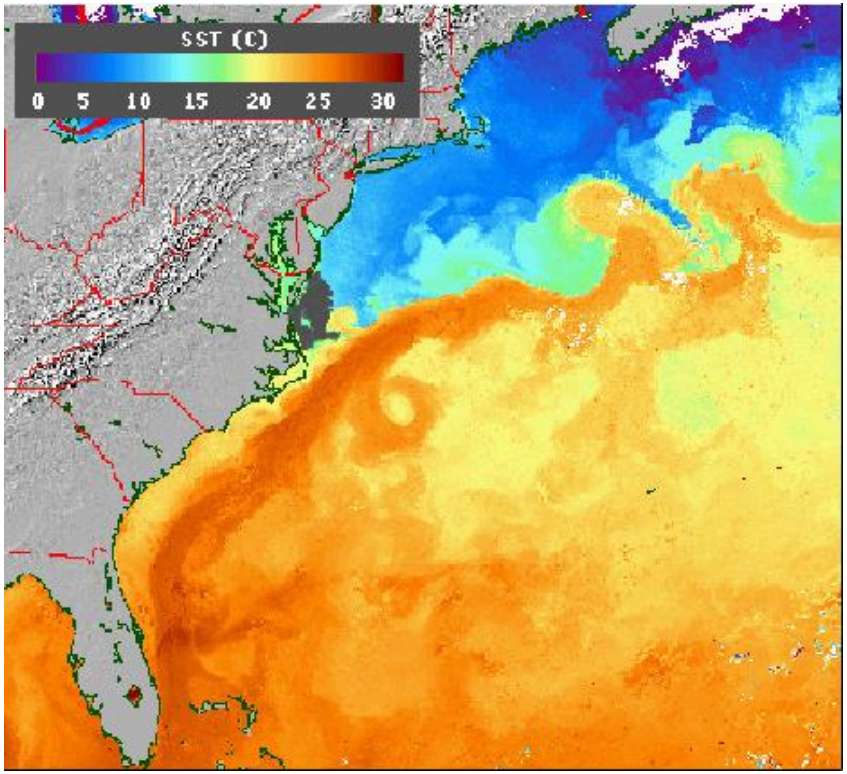
- Decrease 0.036 pH units since 1980
- Decrease of ~0.08 pH units in coming decades

Jamie Scott & Mike Alexander – NOAA OAR ESRL

http://www.esrl.noaa.gov/psd/ipcc/ocn/

Past and Future Climate States

- Physical ecosystem is variable and changing over the long-term



- Salinity
- Ocean acidification
- Wind patterns
- Precipitation
- Streamflow
- Lake ice out
- Nutrients
- Sea level rise
- And more ….

Outline

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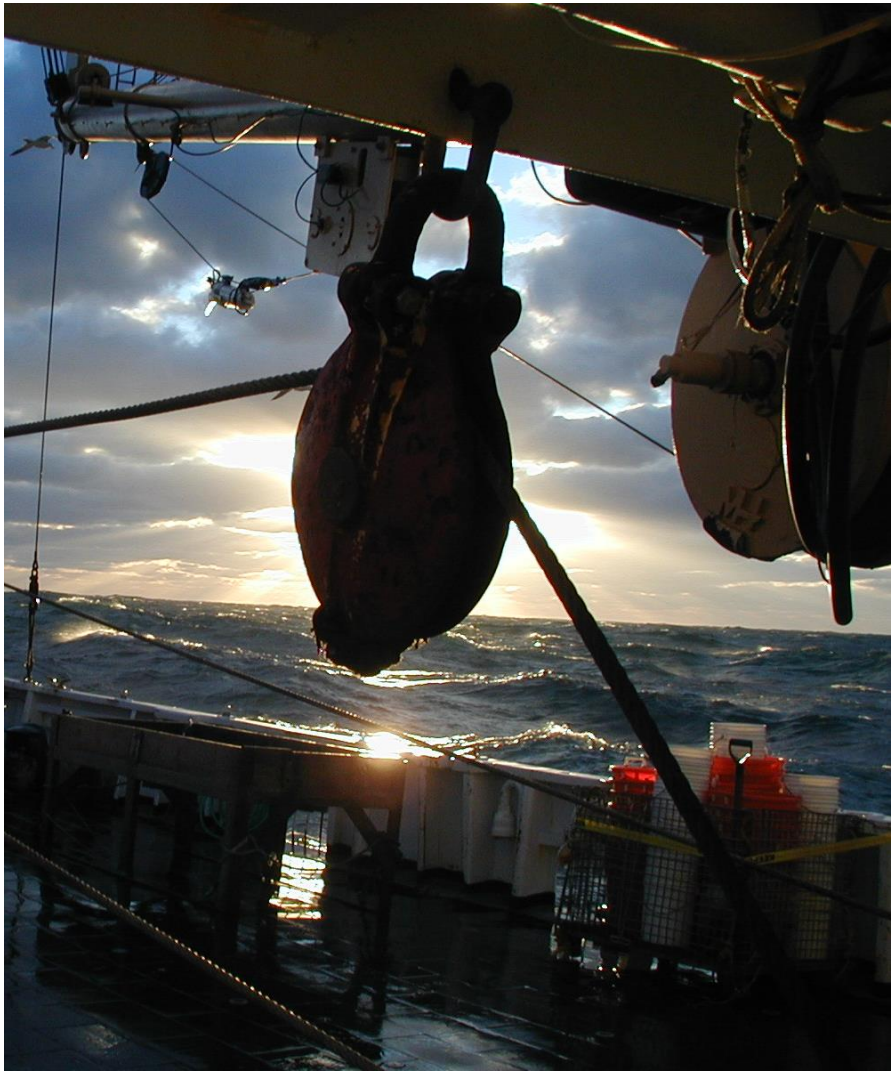
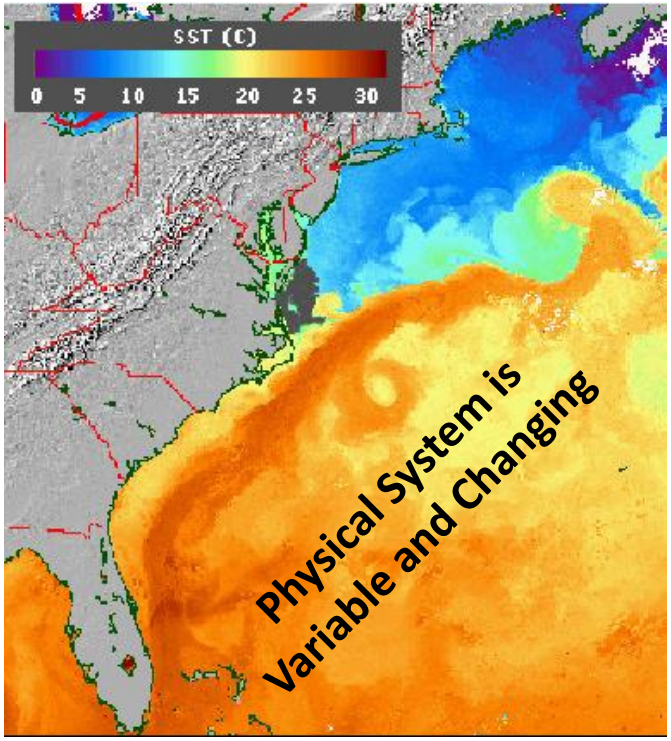
- Past and Future Climate States
- Impacts on Fishery Resources
- Conclusions



Impacts on Fishery Resources

Population – individuals of same species, living in the same geographical area, with capability of interbreeding



1. Abundance
2. Density
3. Dispersion
4. Distribution
5. Demographics (age, sex, etc)
6. Population Growth Rate (births, deaths)
7. Connectivity (immigration, emigration)

Impacts on Fishery Resources

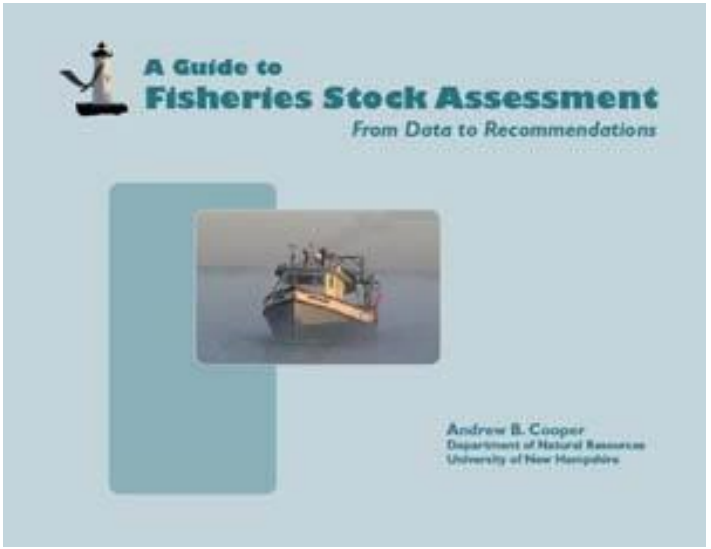
Stock - a group of individuals for which population parameters can be meaningfully estimated for specific management applications

1. Abundance
2. Density
3. Dispersion
4. Distribution
5. Demographics (age, sex, etc)
6. Population Growth Rate (births, deaths)
7. Connectivity (immigration, emigration)

Changes in populations will cause changes in fisheries

Impacts on Fishery Resources

- Traditional stock assessments: only external factor affecting a stock (S) is fishing (F)
- Climate effects integrated in population properties (R, G, Ma, M)



$$S_{R,G,Ma,M} \approx f(\frac{1}{F})$$

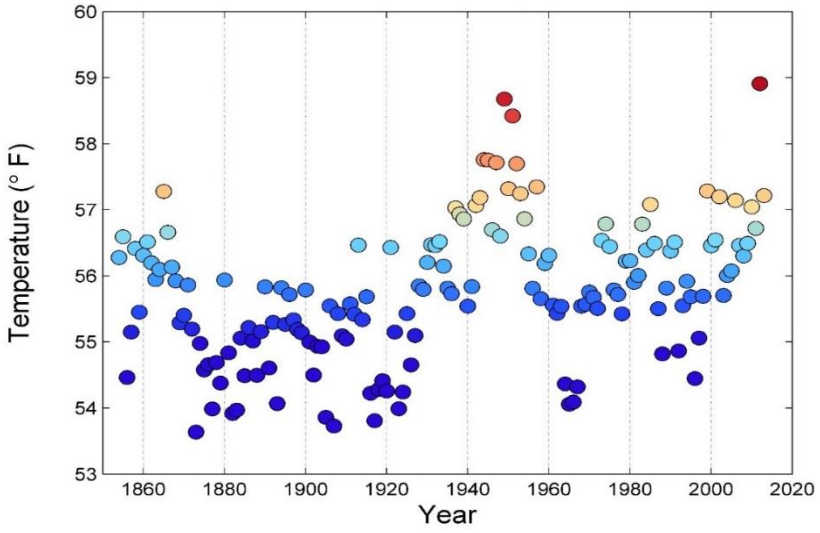
As F increases, S decreases

As F decreases, S increases

http://www.seagrant.unh.edu/news/fisheries-stock-assessment-process

Impacts on Fishery Resources

- Traditional stock assessments:
  - climate effects integrated over hindcast
  - stationary over forecast
- Climate is random with no trend

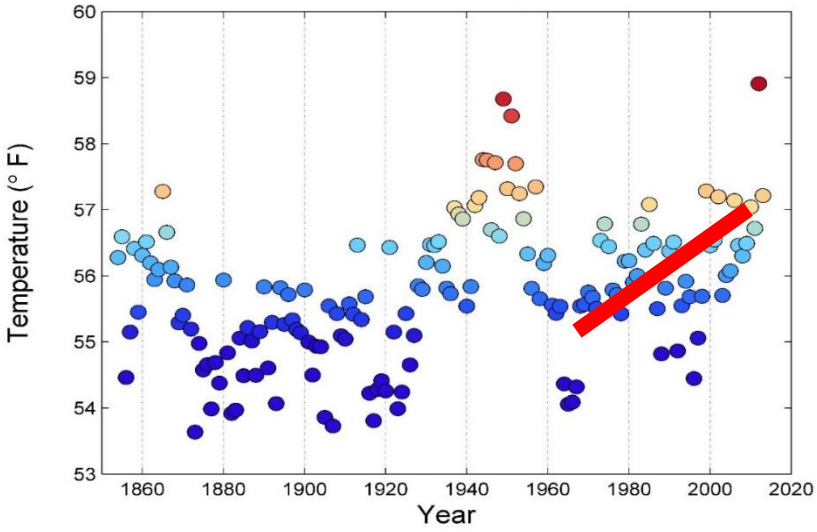


$$S_{R,G,Ma,M} \approx f(\frac{1}{F}) + \varepsilon_C$$

Impacts on Fishery Resources

- Traditional stock assessments:
  - climate effects integrated over hindcast
  - stationary over forecast
- Climate is random with no trend

Climate is changing & climate is variable on decadal scale



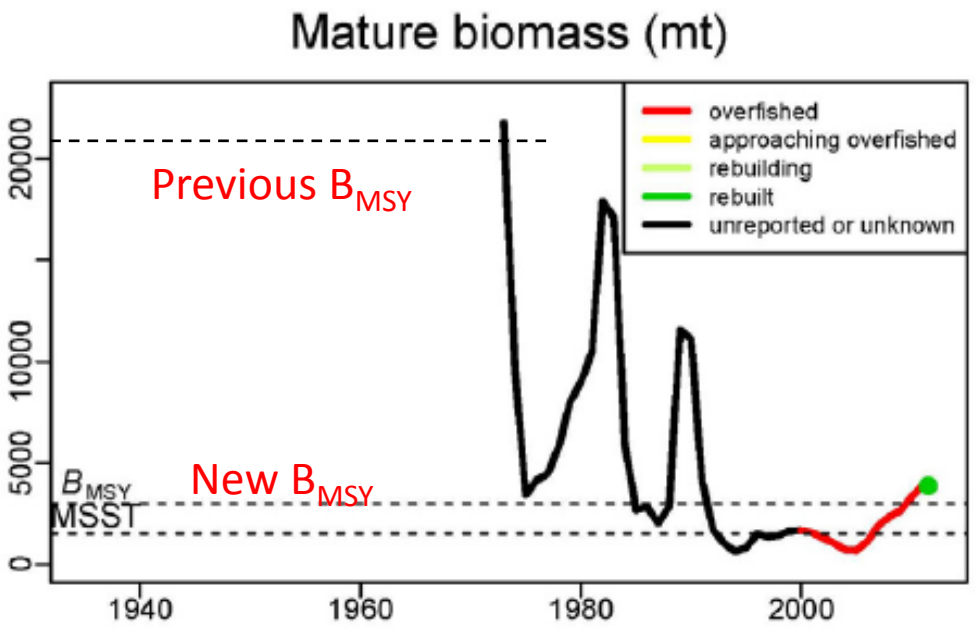
$$S_{R,G,Ma,M} \approx f\left(\frac{1}{F}\right) + g(C)$$

Impacts on Fishery Resources

- Changes in stock productivity (R, G, Mat, Fec)
- Changes in distribution (stock definition; catchability)
- Changes in species interactions (natural mortality, growth)

Impacts on Fishery Resources

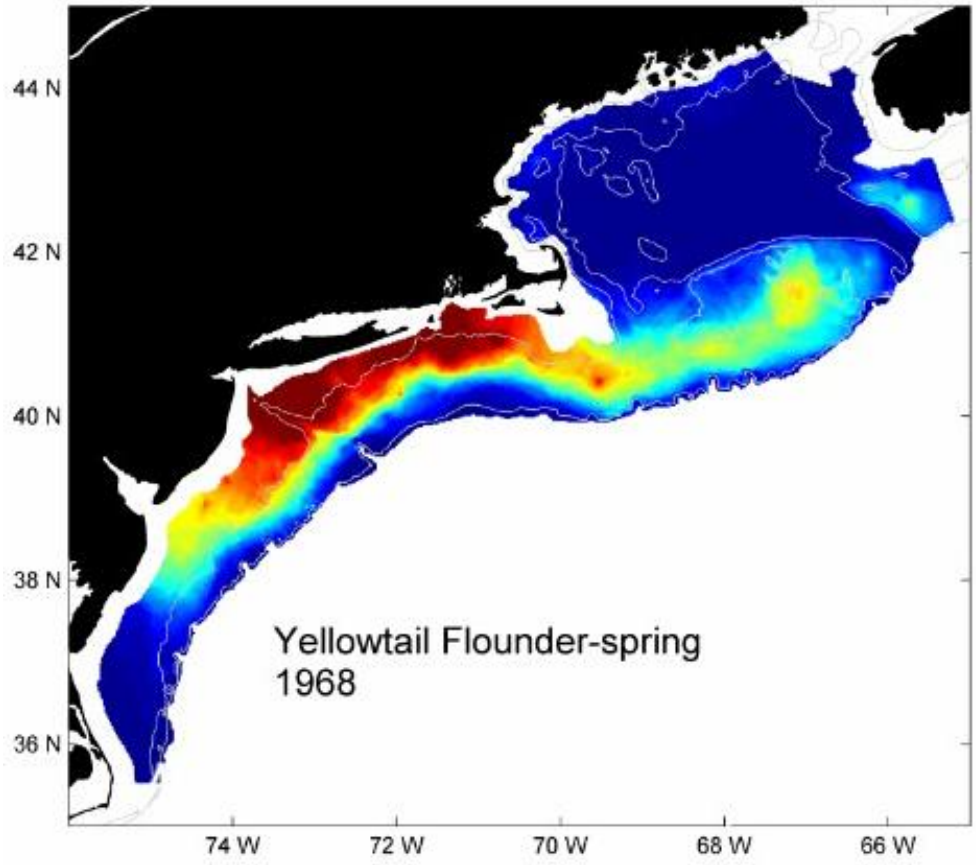
- Changes in stock productivity
- Southern New England yellowtail
- Reduced R associated with cold pool or regime shift



http://nefsc.noaa.gov/publications/crd/crd1218/partb.pdf
http://www.nap.edu/catalog.php?record_id=18488

Impacts on Fishery Resources

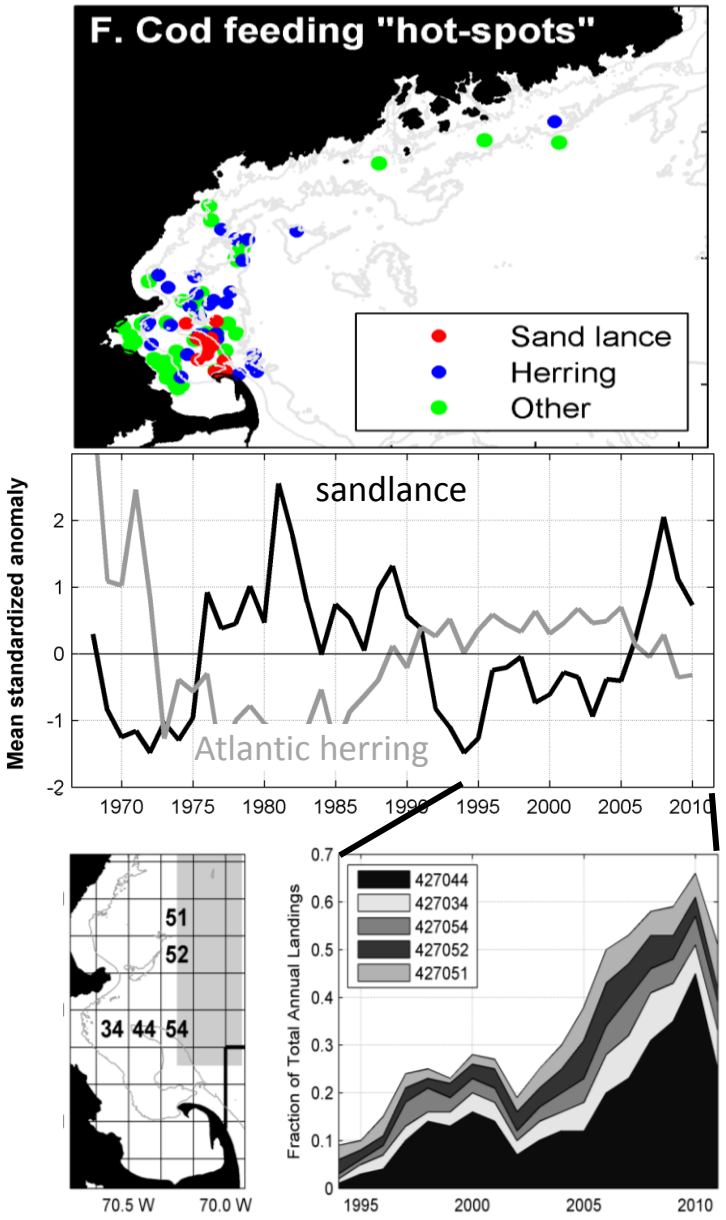
- Changes in distribution
- Stock boundaries / catchability
- 24 of 36 fish stocks shifted poleward / deeper (Nye et al. 2009)



http://www.int-res.com/abstracts/meps/v393/p111-129/
http://www.nefsc.noaa.gov/epd/ocean/MainPage/ioos.html

Impacts on Fishery Resources

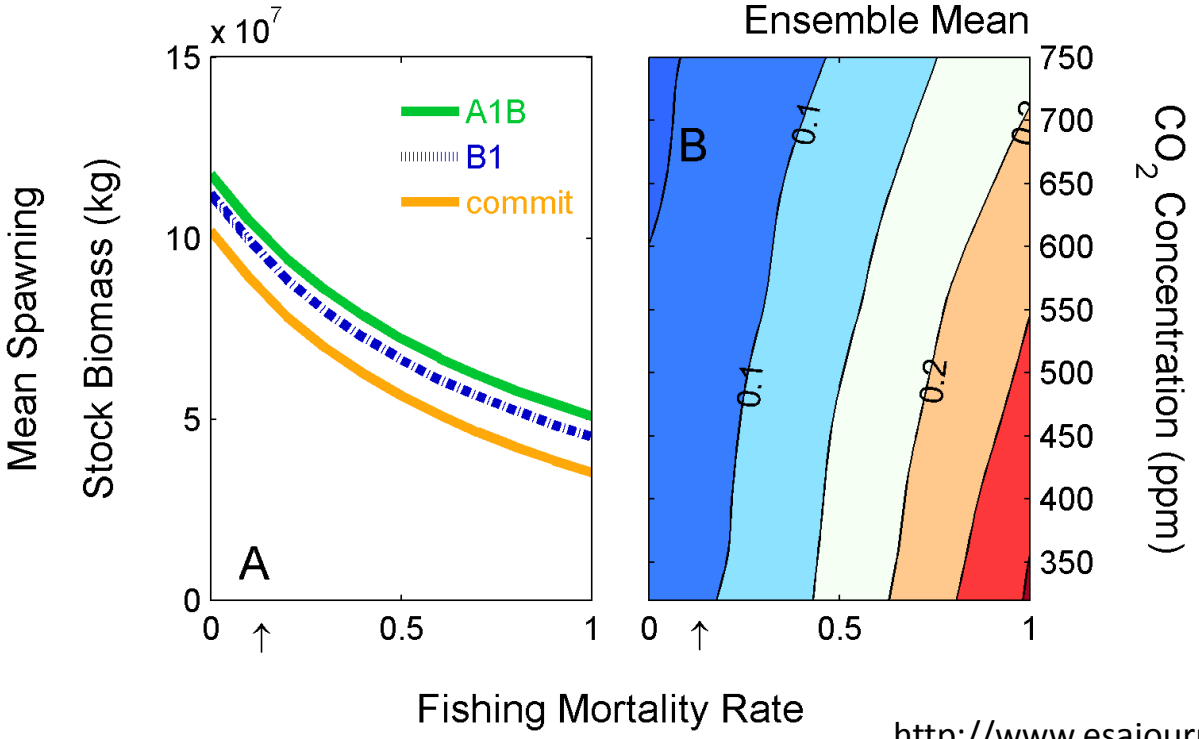
- Changes in trophic interactions
- Cod changing distribution as a result of shift in prey (not necessarily climate related but …)



Richardson et al. in review. Can J Fish Aquat Sci

Impacts on Fishery Resources

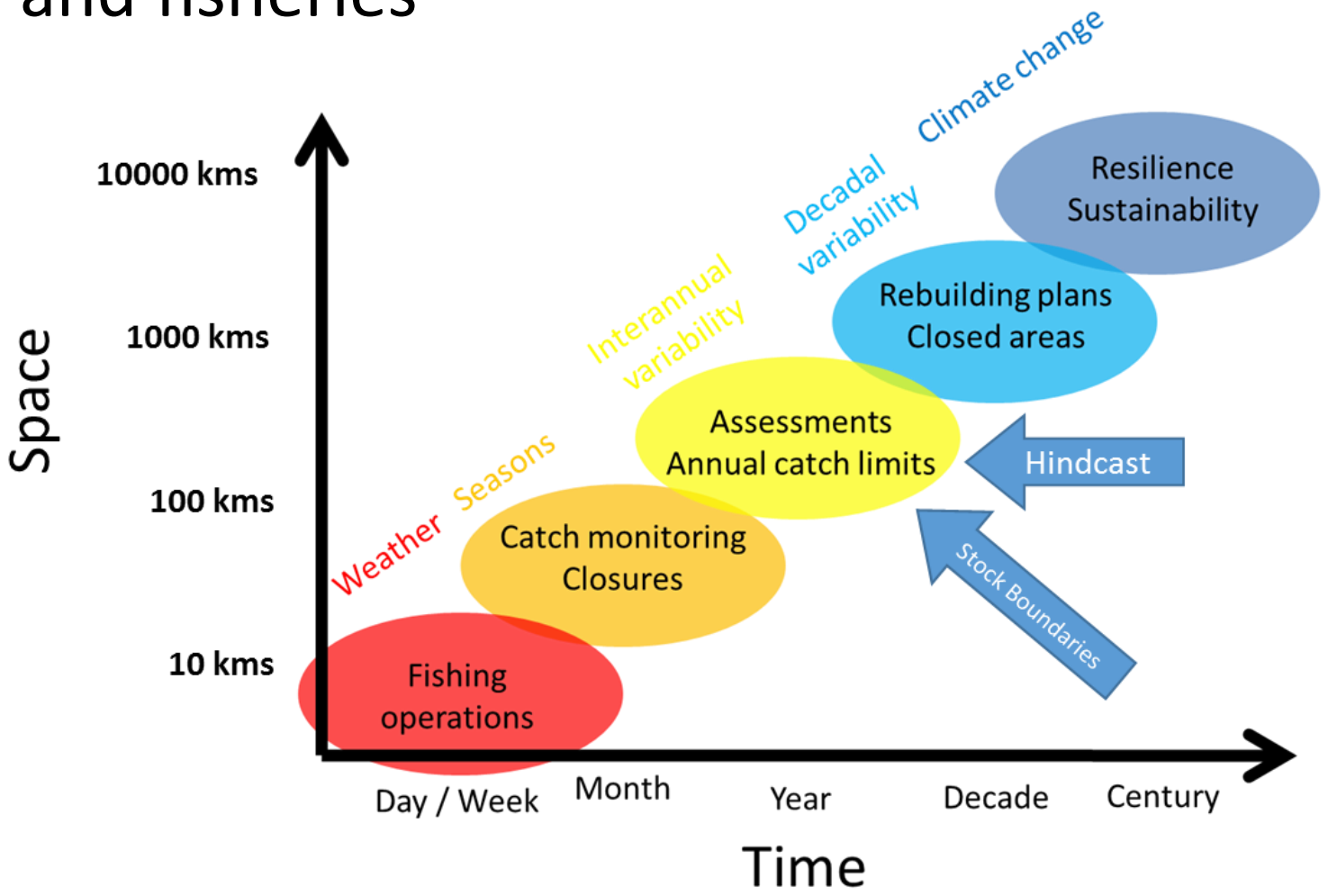
- Not only climate change; not only fishing
- Croaker biomass dependent on both fishing and climate



http://www.esajournals.org/doi/abs/10.1890/08-1863.1

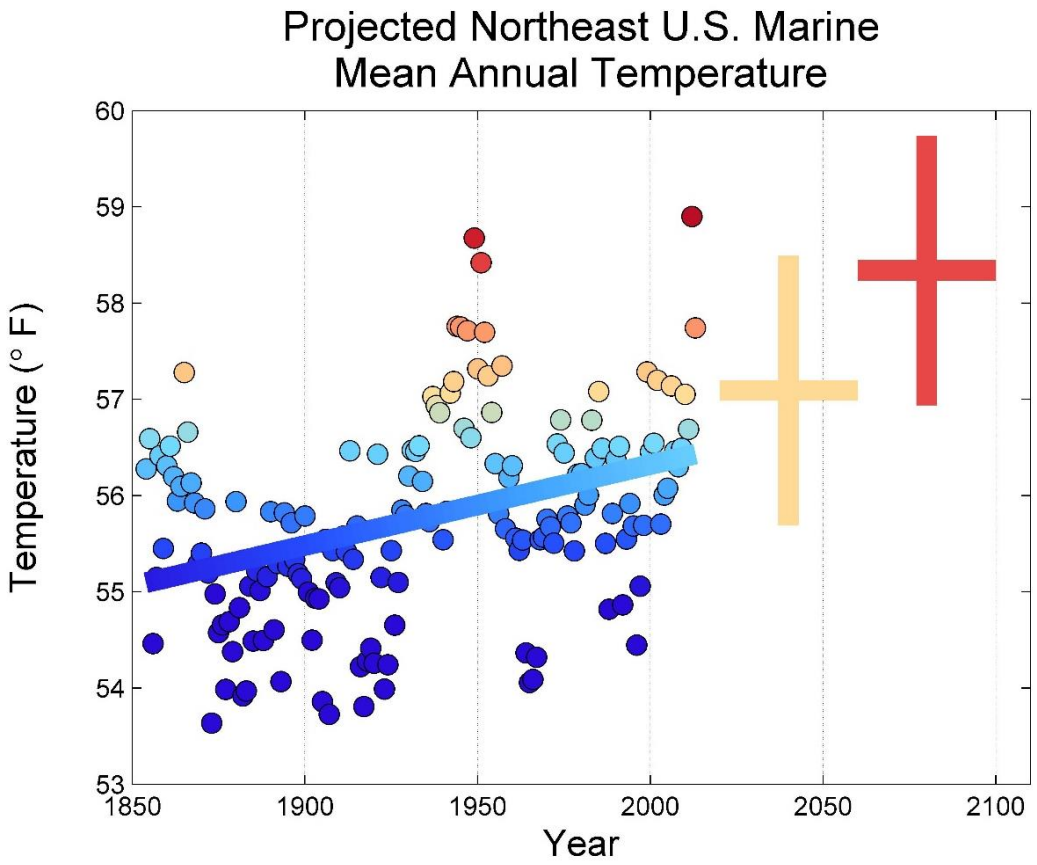
Impacts on Fishery Resources

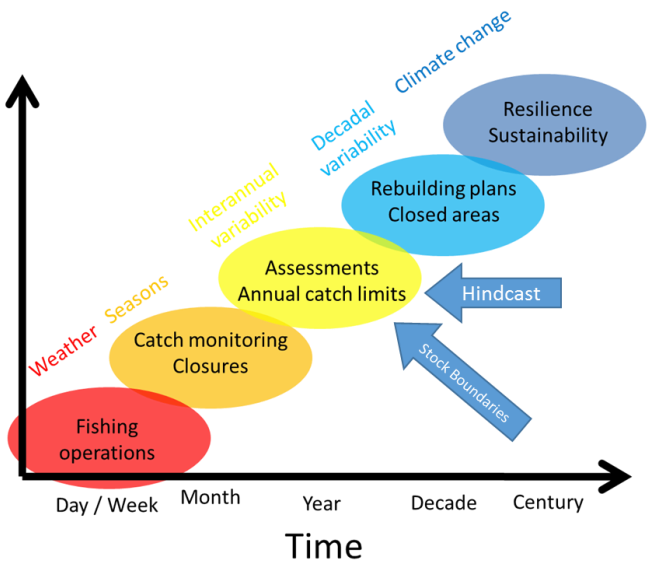
- Interactions between climate and fisheries



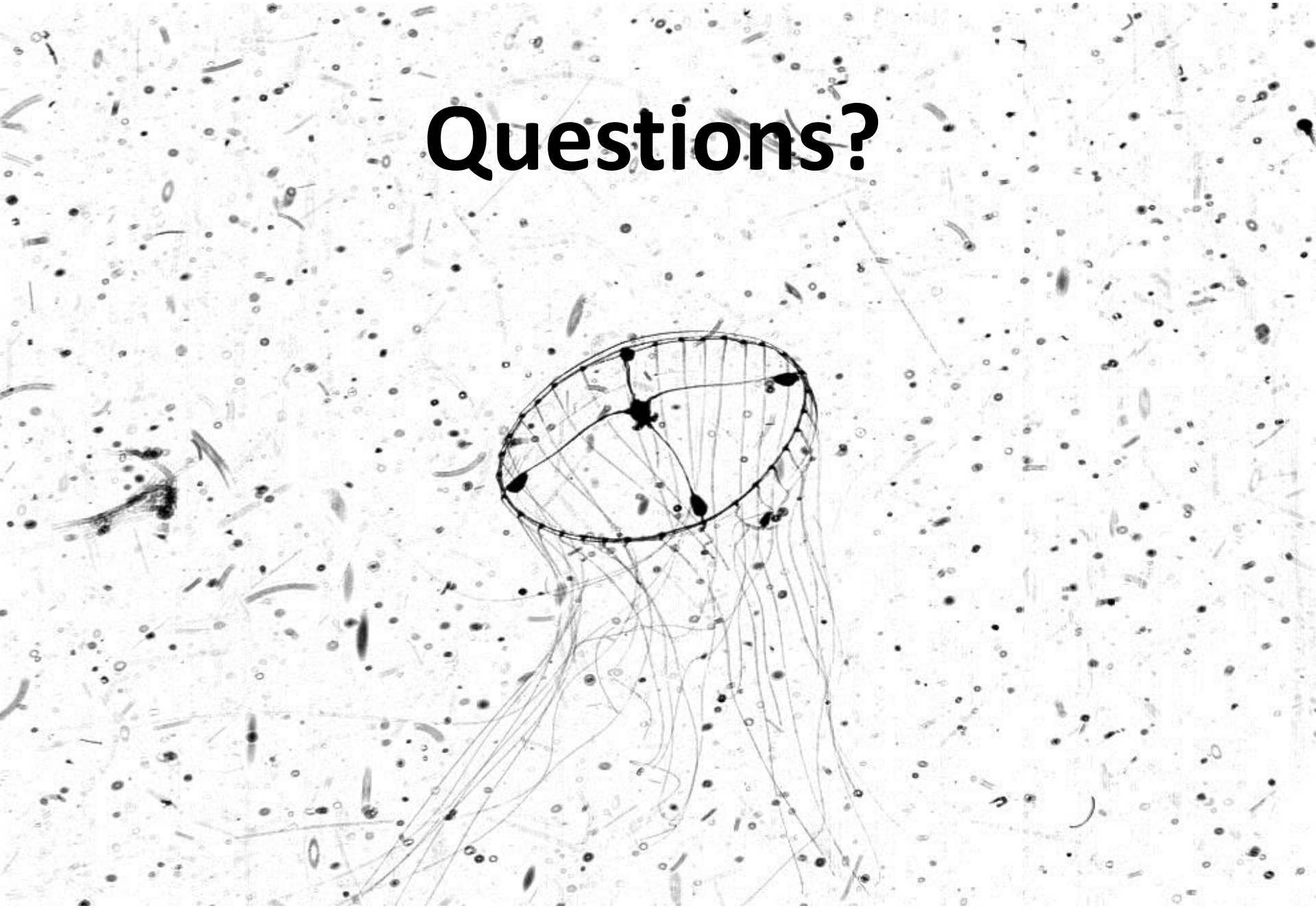
Impacts on Fishery Resources

- Climate change and variability are not just future issues; past, present and future





Questions?



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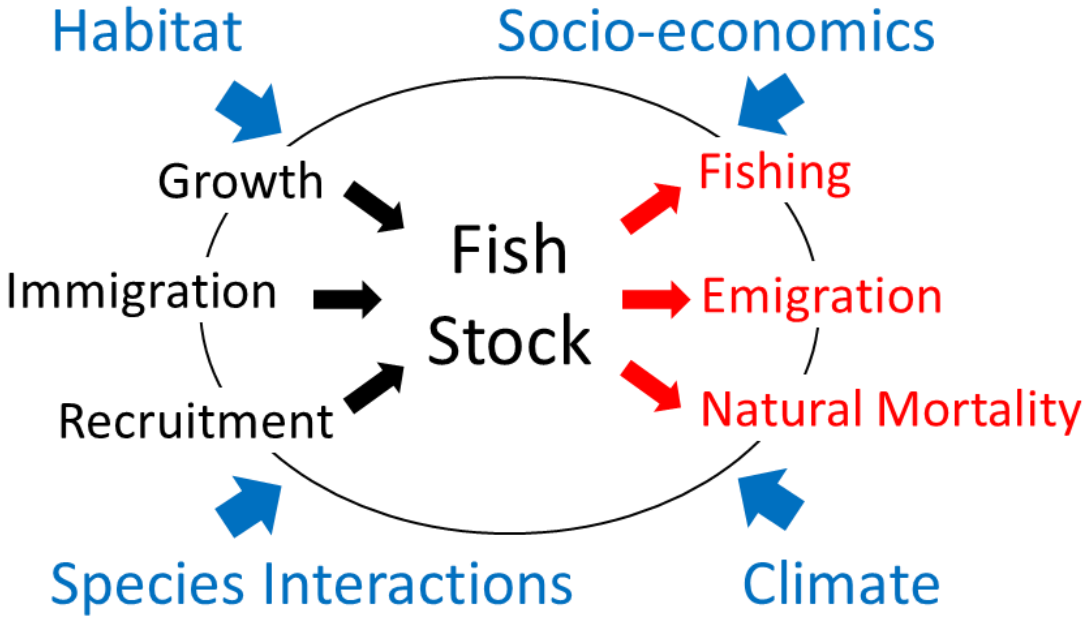
Conclusions

- Reference points are not static
- Stock boundaries are not fixed
- Trophic interactions and community make-up are changing
- Multiple stressors (not all fishing, not all climate)



Conclusions

Steps forward:

- Coupled fisheries dynamic – climate models
- Coupled distribution – climate models

Quantitative

- Atlantic cod
- Atlantic croaker
- River herring
- Cusk
- Others

- Vulnerability assessment — Qualitative
- Outreach — e.g., this talk

Conclusions

Northeast Fisheries Climate Vulnerability Assessment (79 species)

Exposure

Sea surface temperature*
Air temperature*
Salinity*
Ocean acidification (pH)*
Precipitation*
Currents**
Sea level rise**

**modelled results (mean & variance)*
***written description only*

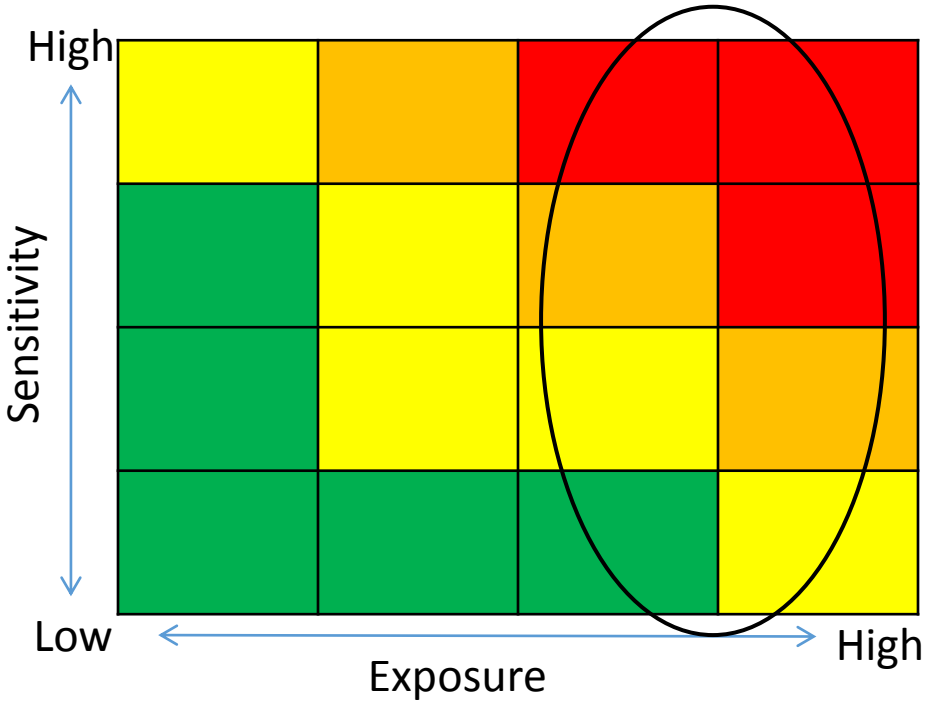
Sensitivity

Habitat Specificity
Prey Specificity
Sensitivity to Ocean Acidification
Sensitivity to Temperature
Stock Size/Status
Other Stressors
Adult Mobility
Spawning Cycle
Complexity in Reproductive Strategy
Early Life History Survival and Settlement Requirements
Population Growth Rate
Dispersal of Early Life Stages

http://www.st.nmfs.noaa.gov/ecosystems/climate/activities/assessing-vulnerability-of-fish-stocks

Conclusions

Northeast Fisheries Climate Vulnerability Assessment (79 species)



- Exposure to climate change of all species is moderately high to high
- Sensitivity higher for diadromous and shellfish; lower for groundfish and pelagics

Questions?

Chris Melrose (NEFSC)